MPR then goes on to compare PIMS to NWN using their assumption that disables the polling channel.

PIMS Capacity (4800bps -10 hr busy period)

	PageMart	MPR	Difference Factor
Polling Channel	450,080	12,000	(37.5X)
Data Channels (Geographical Cells Only)	35,000	N/A	-
Data Channels (Geo., Building & Office Cells)	109,000	N/A	-

Therefore, frequency reuse is not relevant, and building and office cells are also not relevant to MPR's analysis. However, looking at their analysis (which they say is the same), one sees what system throughput enhancing assumptions they have used to enhance NWN's net data rate:

NWN

5 Channel Data Rate (250 kHz)

$$@\ 8{,}150 \text{ messager/hr.} \times \frac{6{,}000 \text{ Bytes}}{\text{Message}} \times \frac{8 \text{ Bits}}{1 \text{ Byte}} \times \frac{\text{hr.}}{3600 \text{ Sec}} = 108{,}667 \frac{\text{Bits}}{\text{Sec}}$$

1 Channel Data Rate (50 kHz)

$$\frac{108{,}667}{5} = 21{,}733 \text{ bps Net or (91\% efficient)}$$

Therefore, system overhead (location, ACK/NAK, check sum only) equals (24,000 - 21,733)/24,000 = 9.4%. PIMS however adds 42% forward correction and other overhead for POCSAG. It is therefore interesting to note the MTel claims that NWN has POCSAG forward error correction, but does not include it in their calculations (PIMS assumes a 42% reduction in throughput) that assumes NWN total overhead is a mere 9°

C. Comments to Comparison of Maximum Capacity of PageMart and MTel Messaging Services.

MPR claims NWN has 2.5 times the capacity of PIMS.

> "This brief analysis shows that the MTel NWN system supports nearly 2.5 times as many subscribers as the PageMart PIMS systems, when considering the bits delivered per frequency domain, time domain and space domain."

PIMS has an order of magnitude more capacity than NWN on a per hertz per MSA basis. The reason the result was achieved is that (1) MPR reduced PIMS polling channel capacity by a factor of 37.5 times and (2) neutralized the capability of PIMS, by assumption (1), to employ frequency reuse either in geographical cells or building cells. In effect the 6001 messages/hour results converts PIMS to a simple simulcast system operating at a gross data rate of 9.6K bps in a 25 kHz channel. However, PageMart has shown that none of MPR's key assumptions are correct. If the aforementioned corrections are used, the following is a valid comparison between PIMS and NWN, using MPR's own assumption and analysis of relatively short message size (3,000 characters):

Subscriber Capacity Comparison (Major MSA)

System	Phase	Rate (bps)	Geographical Cells Only**	Geo., Building and Office Cells
MPR analysis				
PIMS	growth	4,800	46,161	-
NWN	mature	24,000	81,635 (114,500 CRC only)	N/A
PageMart analysis				
PIMS	growth	4,800	190,000	590,000
PIMS	growth	9,600	380,000	1,180,000
PIMS	mature	4,800	286,000	867,000*
PIMS	mature	9,600	572,000	1,734,000*

* Limited by polling channel capacity
** With Forward Error Correction

Assumptions:
1. Same as MPR except for Polling Channel
2. PIMS has 58% POCSAG protocol efficiency (forward error correction and sync bit)
3. NWN has 83% protocol efficiency (no forward error correction simply CRC error detection)
4. Each system uses 250 KHz

Therefore, when the false MPR assumptions are removed, the real comparisons dramatically favor PIMS and its <u>ability to substantially grow the number of cells in buildings and offices over time</u> for further frequency reuse. NWN however is "capped" on capacity as are all simulcast paging systems.

Exhibit 1

United States Patent [19]

Lee

[11] **Patent Number:** 4,932,049

[45] **Date of Patent:** Jun. 5, 1990

[54] **CELLULAR TELEPHONE SYSTEM**

[75] Inventor: William C. Lee, Corona Del Mar, Calif.

[73] Assignee: PacTel Corporation, San Francisco, Calif.

[21] Appl. No.: 307,070

[22] Filed: Feb. 6, 1989

[51] Int. Cl.^{5} H04B 7/10

[52] U.S. Cl. 379/60; 455/33; 379/59

[58] Field of Search 379/58, 59, 60; 455/33

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,144,411	3/1979	Frenkiel	379/60
4,485,486	11/1984	Webb et al.	455/33
4,704,734	11/1987	Menich et al.	455/33
4,727,590	2/1988	Kawano et al.	455/33
4,755,998	10/1988	Felix et al.	379/59
4,771,448	9/1988	Koohgoli et al.	379/60
4,790,000	12/1988	Kinoshita	379/59
4,794,635	12/1988	Hess	379/60
4,799,253	1/1989	Stern et al.	379/59

Primary Examiner—Robert Lev
Attorney, Agent, or Firm—McCubbrey, Bartels, Meyer & Ward

[57] **ABSTRACT**

A cellular telephone system is described of the type wherein a plurality of contiguous cells, each having a different assigned set of transmission frequency channels, are arranged with handoff circuitry for maintaining continuous communication with mobile telephones moving from cell to cell. The system includes at least one cell having a plurality of transmitting and receiving antenna sets. Each set is positioned at a respective antenna sub-site at the perpihery of the cell or other suitable location, and is configured so that propagation and reception of signals is limited to substantially within the boundaries of the cell. Control circuitry monitor the strength of the signal received by each of the antenna sets at each frequency channel in the assigned set. Transmission, at each frequency channel in the assigned set, is confined to the antenna set at one sub-site in the cell having the strongest received signal at each frequency.

15 Claims, 2 Drawing Sheets

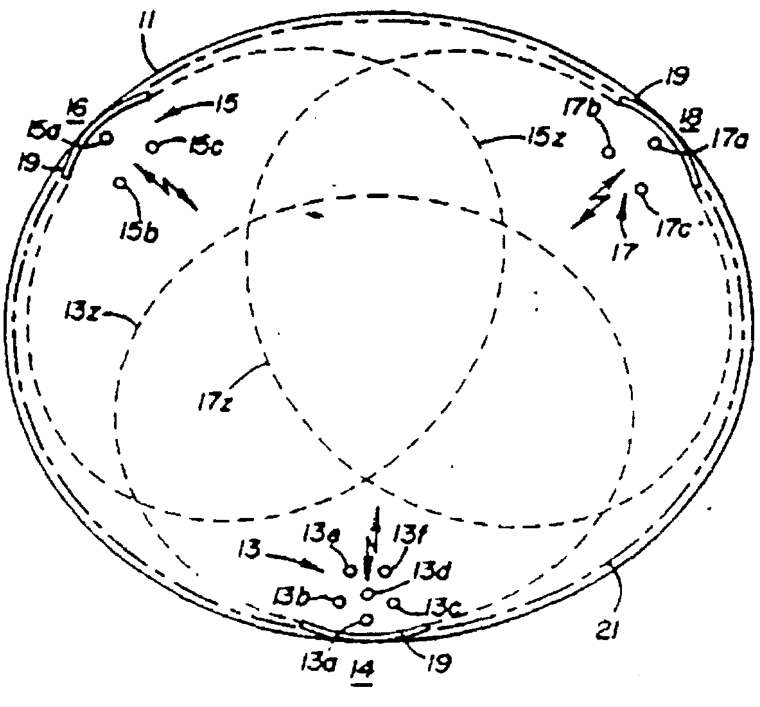
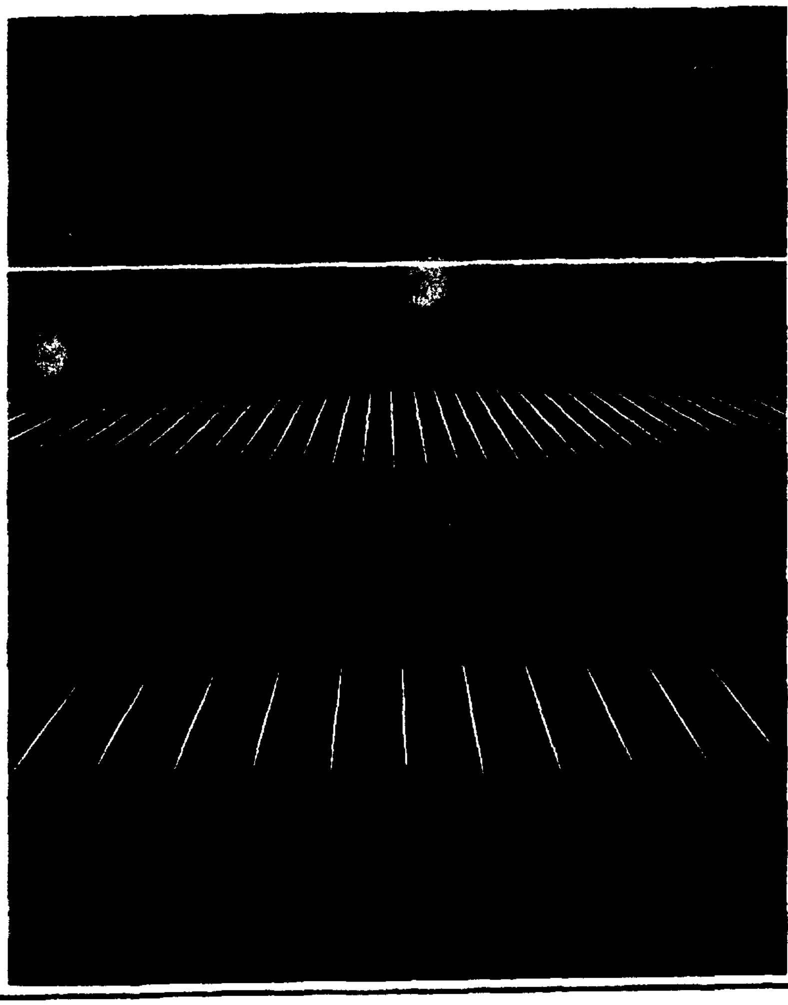


Exhibit 2

MicroLite™
Fiber Optic

Decibel Multi Media Microcell Systems

WHERE COMMUNICATION
TECHNOLOGIES MEET



Increase Service Area Capacity And Add Cellular Subscribers.

Most cellular telephone users, especially those who use hand-held phones, know the feeling of being disconnected suddenly, without warning. It may happen while you're driving in congested rush-hour traffic, or as you enter a canyon, tunnel, parking garage or building. It may even happen as you walk or drive through an airport or around a corner.

The problem is often traced back to insufficient capacity in high-demand areas, or to "dead or weak spots" created by obstructions such as high-rise buildings, parking garages or tunnels. The solution: MicroLite,™ the patented fiber optic microcell system developed by Decibel.

Provide Clean, Clear Signals In Congested Or Blocked Areas.

MicroLite was designed to meet the growing demands of system operators for increased cellular subscriber capacity and improved area coverage. By locating the microcell where the subscribers are concentrated such as in downtown areas, buildings, airports or convention centers, MicroLite provides improved coverage and enhanced system capacity.

In highly congested areas, a series of individual MicroLite units operating as stand-alone microcells can be used to divide existing cells and increase the call handling capacity in crowded cellular areas. Several MicroLite units can be placed at one location to form sectorized microcells.

The Power And Flexibility Of Fiber Optics.

MicroLite microcell is a compact, fiber optic-based, low-power device with the ability to enhance cell site coverage and capacity with unmatched flexibility. All signal processing takes place at the cell site. Radio signals travel to and from the cell site over optical fibers. This high-quality, lightweight media allows unprecedented flexibility. The cellular network designer is no longer constrained by site selection criteria dictated by the need to have radios and associated equipment at the antenna site.

A complete fiber optic microcell system includes a cell site optical interface panel and a remote transceiver enclosed in a weather-resistant cabinet. The remote contains a linear RF power amplifier, a low noise receiver amplifier, transmit and receive filters, an optical transmitter and optical receiver. Several power output options are available to meet a variety of coverage and capacity requirements. An optional alarm system is available to monitor and report on the status of the remote transceiver.

For cellular systems, MicroLite offers more than just a "fill in" system. It provides an exciting link to the future of personal communications. The small size and "go anywhere" design of the remote transceiver allows new flexibility to locate cell sites where they are needed most. MicroLite eliminates problems associated with environmental and aesthetic objections, exorbitant real estate costs, zoning problems or unavailability of site locations.

MicroLite Handles TDMA, CDMA As Well As Narrow Band And Traditional Analog AMPS.

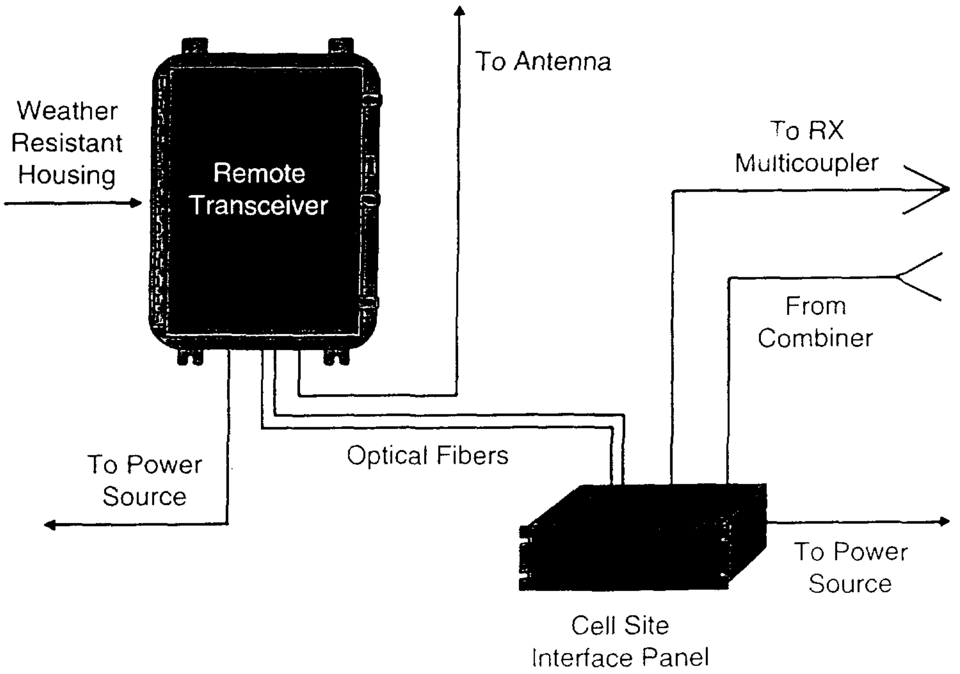
The MicroLite system is designed to be transparent to the cell site. This ensures that the investment in microcell equipment will continue to perform even if you change MTSO or base station suppliers. High linearity throughout the system ensures compatibility with TDMA, CDMA and N-AMPS as well as regular analog systems. This linear design supports both today's analog systems and tomorrow's digital modulation techniques. System capacity can be 70 or more analog channels. Distances between the cell site interface and the remote transceiver can be as long as 24 miles (40 km), and can fill in RF dead spots several miles across.

Place Cell Sites At Convenient, Economical Locations.

In most urban areas, cost effective cell sites are not always available. With MicroLite's compact size and flexibility, you can select the ideal location for maximum cell site coverage at the lowest cost. MicroLite mounts easily on utility poles, billboards, buildings and at a variety of unobtrusive locations that provide the optimum coverage for high use cellular areas. There is no need for building additional towers, and expensive site preparation costs are eliminated. Existing cell sites may be used to house equipment serving several microcells, further reducing site costs while improving maintenance speed and efficiency.

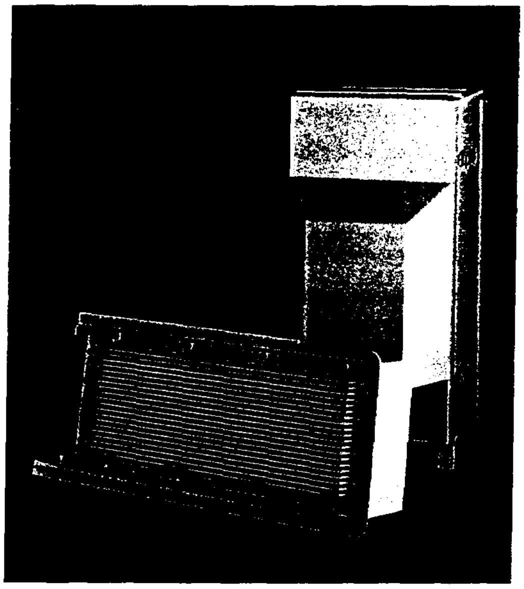
Within metropolitan areas, the microcells can be vertically stacked in office buildings to enhance portable coverage or to form wireless telephone systems. MicroLite units can also operate within or along the edge of an area served by an existing cell site to provide coverage to weak signal areas or dead spots. A series of MicroLite remote transceivers can be located along highways to provide coverage through canyons, valleys or tunnels.

MicroLite is a member of Decibel Products' Multi Media Microcell Systems family. It is designed to work with other products including MicroFill,™ Decibel's Structure Specific 75 ohm communications system, the 16-Channel DB4416 Power Combiner, PrismPlus, and a selection of specialized low-profile interior and exterior antennas. Together, these products provide cellular system engineers with the tools to meet the challenges of today's subscribers while building the foundation for future personal communications networks.



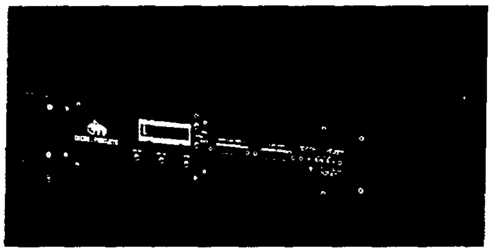
Decibel Is Committed To Your Future Applications.

Decibel products have more than 40 years of development, research and manufacturing behind them. Our technical leadership and dedication to excellence in design and system integration is evident in every product we produce. Service that begins with the initial consultation, continues with comprehensive customer support after the sale. Our 24-hour telephone hotline assures continuous, uninterrupted service. Decibel is committed to providing the most advanced communications technology to accommodate tomorrow's applications.



MicroLite™ Remote Transmit and Receiver Module System with Power Supply/Mount.

Optional RF Alarm System with LCD Display and Open Collector Output.



Cell Site Interface Panel.

DECIBEL

Multi Media Microcell Systems

Where Communication Technologies Meet

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An Alliance Telecommunications Company

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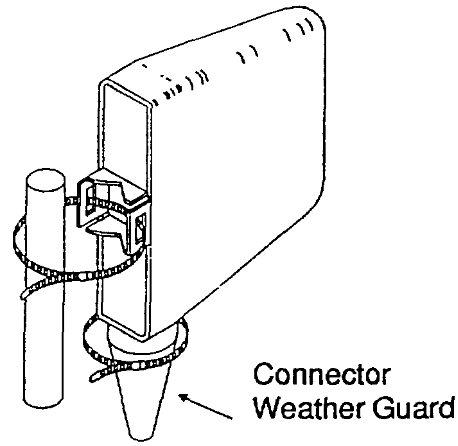
Decibel Products
2-92-5M

DECIBEL PRODUCTS DECIBEL MOBILCOM GMBH

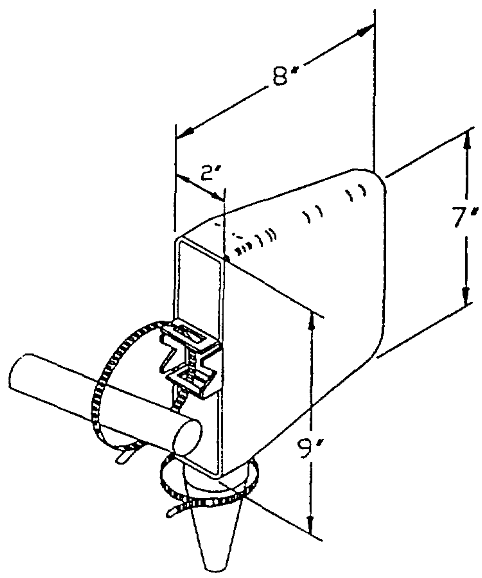
DB471 . -XY

Compact Broadband Directional Antenna
800- 960 MHz

Model Number	DB471N-XY	DB471E-XY
Termination	Type N-Female	7–16 Female
Frequency Range	800-960 MHz	
Gain	5.5dBd (7.6dBi)	
VSWR	1.5 :1 or better	
Beamwidth (3 dB from max)	Horizontal : 110° Vertical : 70°	
Front to Back Ratio	>20 dB	
Polarization	Vertical	
Max. Input Power	60 watts	
Other Information	Mounting bracket can be rotated 90°, Connector weather guard included.	
Weight	2.3 oz. (1000 g)	
Max. Wind Area	64 in^2 (406 mm^2)	
Windload	22 lbs.	
Max. Wind Speed	100 mph. (160 km/std)	
Material	Aluminum base PC Board ABS Radome	
Color	Off-white	
Mounting	Large hose clamp	
Lightning Protection	Metal parts at ground	
Packing Size	12"x12"x10"	
Shipping Weight	4 Lbs. (1800 g)	

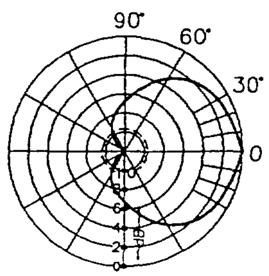


Mounting to a Vertical Member

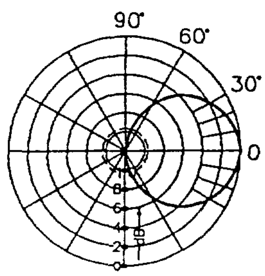


Mounting to a Horizontal Member

Typical Pattern

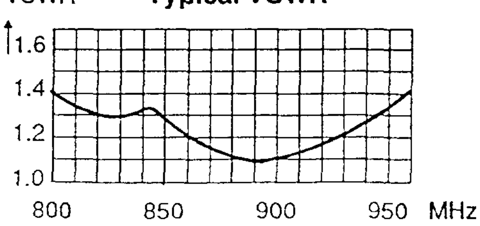


Horizontal



Vertical

VSWR **Typical VSWR**



Gain (over λ/2-Dipole)

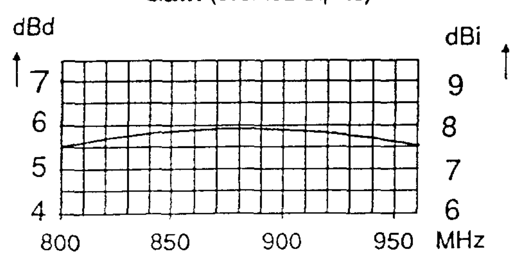


Exhibit 3

I. EXECUTIVE SUMMARY

1.1 General Information

The SmartCELL™ is a Microcell System designed to provide improved Cellular Radio service to areas not covered adequately by existing cellular technology. The SmartCELL™ Microcell System will also provide service to areas with dense user population. The System is also designed to provide these services with a much lower infrastructure cost than conventional Cellular Radio Systems. The SmartCELL™ Microcell System makes extensive use of components developed for small cellular mobile equipment to provide a compact, cost effective response to the recognized need for microcell based Personal Communications Services (PCS).

1.2 General System Operational Description

The SmartCELL™ Microcell System uses Cellular Compatible Mobile Station Radio Transceiver Subsystems to communicate with the radio equipment in the existing cell sites and Cellular Compatible Base Station Transceiver Subsystems in the microcell sites to communicate with portable units within the Microcell coverage area. The transceiver subsystem is interconnected over four wire voice grade facilities through Cell Site Controller Subsystems at the existing Mobile Cell Site and the microcell site respectively.(see Figure 1.1). The use of frequency agile transceivers at each end of the system allows the use of the same control or voice channels that are used at the mobile cell site or of different channels if required by interference or other considerations. It is expected that the voice channels used for microcell service will not be broadcast at the mobile cellular cell site and that the control channel used at the microcell site will be different (offset) than the one used at the cellular cell site. Scanning receiver(s) at the microcell transceiver locations will be used to detect potential interference between the Mobile Cellular and Microcell Systems (foreign carrier detect). Inter-Microcell handoff is being developed for a future compatible add-on release.

The Microcell Common Controller Subsystem can interconnect with both the Microcell Channel Equipment and the Cell Site Channel Equipment by four wire voice grade circuits (metallic or non-metallic). The Mobile Cell Site Transceiver Subsystems can interface with the radio equipment in the existing Cell

Sites either over the air or by direct connections. The various components of the SmartCELL™ Microcell System can be placed in such a manner that the interconnection and operating costs are minimized.

1.3 Compatibility with Existing Equipment

The SmartCELL™ Microcell System is designed to be compatible with existing network hardware and software. The SmartCELL™ Microcell System can also take advantage of the investment in existing cellular infrastructure by using idle capacity in existing Cell Sites to provide service to areas with poor coverage or beyond the current coverage area. The use of widely available four wire voice grade facilities for all interconnections and the compact size of the equipment allows the rapid deployment of Microcell services. The SmartCELL™ Microcell System is capable of operating with existing mobile cellular with appropriate adjustments for channel assignment differences.

1.4 System Capacity and Physical Size

The SmartCELL™ Microcell System can support up to 64 single channel Base Stations with one Cell site Common Controller Subsystem. The required Microcell site based equipment consists of one Microcell Common Controller and from one (1) to sixty-four (64) Microcell Radio Voice Channel Transceivers. The Control Subsystem for a maximum configuration is contained in a single cabinet. The cabinet can be floor or wall mounted and is approximately 22 inches wide, 20 inches tall and 22 inches deep. This cabinet contains all control and switching equipment and power for all directly (metallically) connected to Transceivers or those housed in the Control Unit Cabinet. The Transceivers are contained in an enclosure approximately 20 inches tall 22 inches wide and 5 inches thick. The Transceivers and antennas are contained in a plastic enclosure which can be surfaced mounted on interior walls. They can also be mounted directly in the Control Unit Cabinet. Weatherproof housings and flush mount enclosures are supplied as an option. Optional 115 VAC power supplies are available. Equipment Primary power is 24 VDC. Battery backup is available as an additional option.

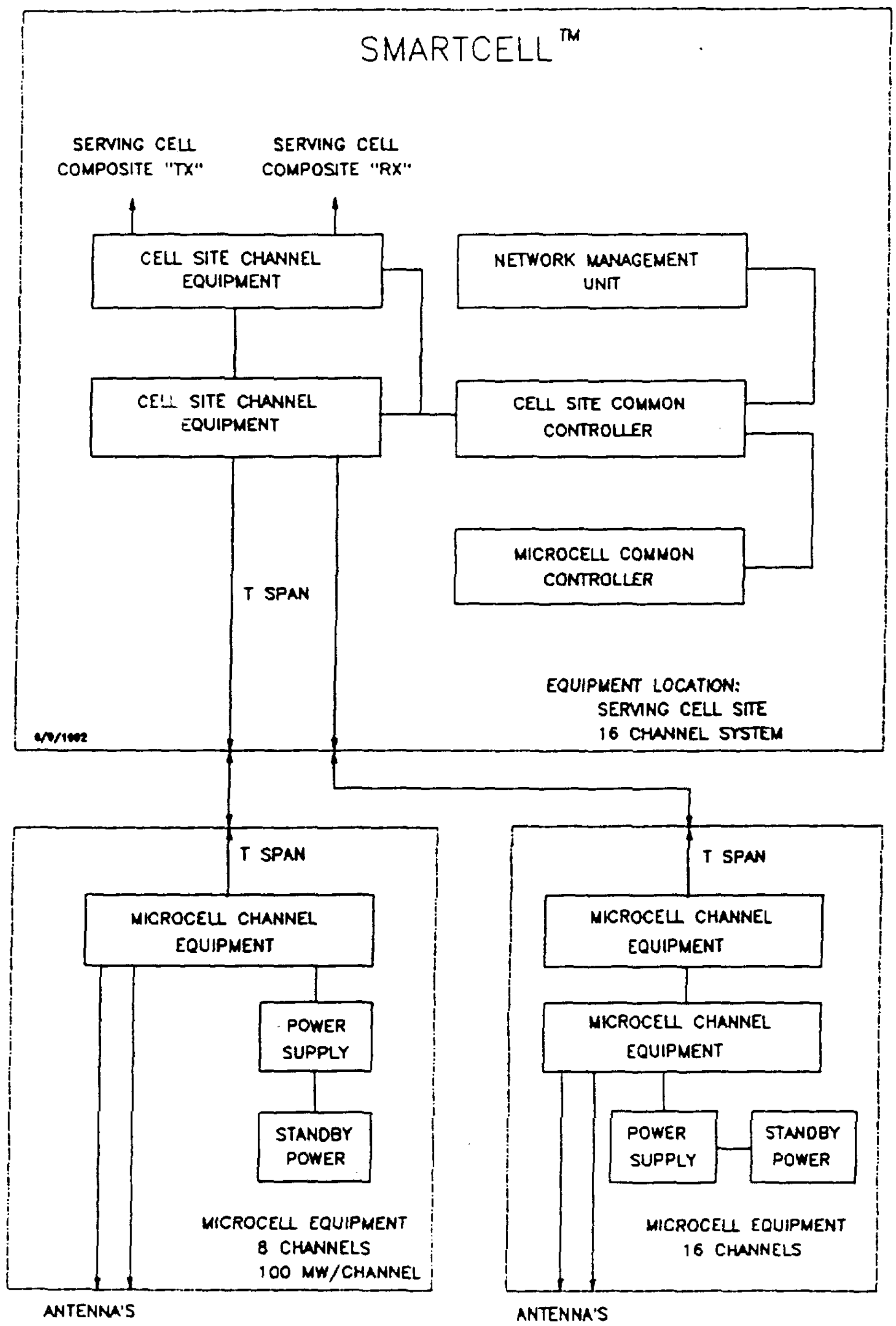


FIGURE 10. EXAMPLE OF SYSTEM EQUIPMENT LAYOUT

5.10

VI TECHNICAL SPECIFICATION

6.1 Electrical Specifications

6.1.1 Cell Site Channel Equipment Unit

TRANSMITTERS

ITEM	SPECIFICATION
Frequency Range	824.040 MHZ to 848.970 MHZ
Frequency Stability	±0.24 PPM
RF Output Power	-40 dBm to -95 dBm (2 dB increments)
RF Power Transition Time	<20 ms
RF Output Power Tolerance	±1 dBM
Channel Switching Time	20 ms Adjacent Channel 40 ms Other Channels
Carrier Inhibit Time	<2 ms
Carrier On-Off Time	<2 ms
Modulation Deviation Limiting	<±12.0 kHz
Modulation Noise & Distortion	<-26 dB
Harmonic & Spurious Emission	<-41
SAT Frequency Deviation	2.0 kHz ±10%

RECEIVERS

ITEM	SPECIFICATION
Frequency Range	869.040 MHZ to 893.970 MHZ
Channel Switching Time	<20 ms Adjacent Channel <40 ms Other Channel
RF Sensitivity	-120 dBm
RF Signal Level Measurement	-120 dBm to -30 dBm in 1 dB steps ±1 dBm
Intermodulation Response	>65 dB
Hum and Noise	<-32 dB
Distortion	-26 db
Spurious Response	<60 dB
Selectivity 6 dB 65 dB	<+18.2 kHz >-18.2 kHz >+40 kHz <-40.0 kHz

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6.1.2 Microcell Channel Equipment

TRANSMITTERS

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Hum and Noise	<-32 dB
Distortion	-26 db
Spurious Response	<60 dB
Selectivity 6 dB 65 dB	<+18.2 kHz >-18.2 kHz >+40 kHz <-40.0 kHz

6.2 POWER REQUIREMENTS AND PHYSICAL SIZE

MICROCELL CHANNEL EQUIPMENT UNIT, fully loaded.

PRIMARY POWER	24 VDC @ 10.5 AMPS
DIMENSIONS HxWxD Inches	3.5 x 19 x 14.5
WEIGHT, lbs.	34

Power consumption by card assembly.

T1	7 watts
Codec	3 watts
Adpcm/codec	3 watts
Base Station Controller	4 watts
Transceiver module	23 watts

CELL SITE CHANNEL EQUIPMENT UNIT, fully loaded.

PRIMARY POWER	24 VDC @ 8 AMPS
DIMENSIONS HxWxD Inches	3.5 x 19 x 14.5
WEIGHT, lbs.	34

CELL SITE COMMON CONTROLLER

PRIMARY POWER	24 VDC @ 1.5 AMPS
DIMENSIONS HxWxD Inches	3.5 x 19 x 23
WEIGHT, lbs.	35

MICROCELL COMMON CONTROLLER

PRIMARY POWER	24 VDC @ 1.5 AMPS
DIMENSIONS HxWxD Inches	3.5 x 19 x 23
WEIGHT, lbs.	35

MICROCELL NETWORK MANAGEMENT UNIT

PRIMARY POWER	24 VDC @ 10.5 AMPS
DIMENSIONS HxWxD Inches	7 x 19 x 18
WEIGHT, lbs.	36

6.3 MICROCELL CHANNEL EQUIPMENT UNIT ELECTRICAL SPECIFICATIONS

ELECTRICAL SPECIFICATIONS OF ASSEMBLY;

PRIMARY POWER	24 VDC @ 10.5 AMPS
RF SECTION	
OUTPUT POWER/CHANNEL (dBm)	
maximum	+20
minimum	-30
RECEIVER SENSITIVITY (dBm)	-105
RX SENSITIVITY W/LNA (dBm)	-120
CHANNEL CAPACITY, PER FRAME	8
T1 CARD	
T1 INTERFACE	DSX-1 OR CSU
E1 INTERFACE	CCITT, G703/704
LINE CODING	B8ZS
FRAME FORMAT	SF OR ESF
LINE RATE T1	1.544 MBPS
E1	2.048 MBPS
56 KBPS INTERFACE	V.35, V.11, DSU
64 KBPS INTERFACE	V.35, V.11, DSU
POWER CONSUMPTION	7 WATTS
CLOCK SOURCE	INTERNAL, EXTERNAL, DERIVED

Exhibit 4

EFFICIENCY OF A NEW MICROCELL SYSTEM

ine

by

W. C. Y. LEE
PacTel Corporation
Walnut Creek, California

I. Introduction

A conventional Microcell uses the cell splitting technique to reduce the size of the cell in order to increase the capacity. In general, when the new cell radius is one half of the old cell radius, the old cell can fit four new small cells. Each small cell would carry the same capacity as the old cell. Then the same areas of the old cell can increase the capacity four times that of the old one. This increases the system capacity. The measured system capacity is the number of channels per square miles or square kilometers. However, when the cell becomes small, the four times of capacity increase will not be observed. This is due to the fact that the interference is harder to control in small cells then in larger cells. When a cell radius is less than 1 kilometer, the cell splitting may only increase system capacity by two times. The radius capacity, m, is defined as the number of cahnnels per cell expressed as follows:

$$m = \frac{M}{K} \qquad \text{number of channels / cell}$$

where M is the total channels and K is the frequency reuse factor. m is inversely proportional to K. m is a fixed number depending on which specified radio equipment is deployed in the cellular system. The size reduction of a cell does not change the radio capacity. In today's analog cellular system, an accepted voice quality has to be maintained by engineering the frequency reuse factor K = 7, i.e., the co-channel cell separation D = 4.6R, or the carrier-to-interference ratio, C/I, $(C/I)_s = 18$ dB. In this paper a new Microcell system[1] can be implemented for increasing not only system capacity but also radio capacity.

II. A New Microcell System Design

A Microcell is divided into three (can be more than three) submicrocells which are also called zones. In each zone there is a zone site at which the antenna and the radios are installed. The zone site can be located at the center of each zone (see Fig. 1) or at one edge of each zone (see Fig. 2). When a vehicle is at one of the three zones, all three zones receivers receive the signal strengths from the vehicle transmitter. After comparing the signal strengths, the zone transmitter which site receives the strongest strength is turned on to serve the mobile. When the vehicle is moving to another zone, the new zone transmitter is turned on and the old zone transmittrer is turned off. The same frequency is used by the vehicle. Therefore, no handoff action is taken by the MTSO. There is only one zone transmitter turned on but all three zone receivers are turned on for any one frequency which is associated with a vehicle. A Microcell may handle 60 frequencies assigned to 60 vehicles. In average, each zone may handle 20 mobile calls associated with 20 frequencies.

III. Efficiency of the New Microcell System

The new Microcell System can be implemented in three different approaches.

A. Selective Omni-zone Approach

We may place a zone site at the center of each zone as shown in Fig. 1. The transmit power of each zone site would be center excited. In this case, we can

EFFICIENCY OF A NEW MICROCELL SYSTEM

ane

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I. Introduction

A conventional Microcell uses the cell splitting technique to reduce the size of the cell in order to increase the capacity. In general, when the new cell radius is one half of the old cell radius, the old cell can fit four new small cells. Each small cell would carry the same capacity as the old cell. Then the same areas of the old cell can increase the capacity four times that of the old one. This increases the system capacity. The measured system capacity is the number of channels per square miles or square kilometers. However, when the cell becomes small, the four times of capacity increase will not be observed. This is due to the fact that the interference is harder to control in small cells then in larger cells. When a cell radius is less than 1 kilometer, the cell splitting may only increase system capacity by two times. The radius capacity, *m*, is defined as the number of cahnnels per cell expressed as follows:

$$m = \frac{M}{K} \qquad \text{number of channels / cell}$$

where M is the total channels and K is the frequency reuse factor. *m* is inversely proportional to K. *m* is a fixed number depending on which specified radio equipment is deployed in the cellular system. The size reduction of a cell does not change the radio capacity. In today's analog cellular system, an accepted voice quality has to be maintained by engineering the frequency reuse factor K = 7, i.e., the co-channel cell separation D = 4.6R, or the carrier-to-interference ratio, C/I, $(C/I)_s$ = 18 dB. In this paper a new Microcell system[1] can be implemented for increasing not only system capacity but also radio capacity.

II. A New Microcell System Design

A Microcell is divided into three (can be more than three) submicrocells which are also called zones. In each zone there is a zone site at which the antenna and the radios are installed. The zone site can be located at the center of each zone (see Fig. 1) or at one edge of each zone (see Fig. 2). When a vehicle is at one of the three zones, all three zones receivers receive the signal strengths from the vehicle transmitter. After comparing the signal strengths, the zone transmitter which site receives the strongest strength is turned on to serve the mobile. When the vehicle is moving to another zone, the new zone transmitter is turned on and the old zone transmittrer is turned off. The same frequency is used by the vehicle. Therefore, no handoff action is taken by the MTSO. There is only one zone transmitter turned on but all three zone receivers are turned on for any one frequency which is associated with a vehicle. A Microcell may handle 60 frequencies assigned to 60 vehicles. In average, each zone may handle 20 mobile calls associated with 20 frequencies.

III. Efficiency of the New Microcell System

The new Microcell System can be implemented in three different approaches.

A. Selective Omni-zone Approach

We may place a zone site at the center of each zone as shown in Fig. 1. The transmit power of each zone site would be center excited. In this case, we can calculate theC/I ratio from the new system shown in Fig. 3. The separation D_1 of any two nearest co-channel zones (worst case scenario) in two corresponding microcells is $4.6R_1$. Where R_1 is the zone radius, this separation proves the voice quality of the new Microcell is better than that of the regular analog system. The C/I ratio of a worst case scenario is also calculated. In this scenario, the co-channel vehicles operate in their zones of corresponding cells are within the circle shown in Fig. 3. The interfering zones are identified by A-zones and three B-zones. The serving zone is in the center cell and is indicated by R_1. Then

$$C/I = \frac{R_1^{-4}}{\sum D_i^{-4}} = \frac{R_1^{-4}}{\underbrace{3(4.6R_1)^{-4}} + \underbrace{3(5.75R_1)^{-4}}} = 105\ (=)\ 20\,dB$$

indicates that even in a worst case scenario of this Microcell system, the C/I is 2 dB better than the regular analog system. Also in Fig. 3, we can show that the separation of co-channel cells is D = 3R where R is the cell radius. Since

$$K \triangleq \frac{(D/R)^2}{3} = 3$$

the new Microcell system proves the increase of radio capacity as K = 7 for a regular cell system to K = 3 for this microcell system which increases 7/3 or 2.33 times. K = 3 is the smallest number in a cellular system regardless of whether it is an analog or digital system except for a CDMA system in which K approaches one. This omni-zone approach provides a superior voice quality in the K = 3 system. However, it is costly to find three center locations of three zones. Also in reality, the control of the transmitted power in omni-zones is difficult. Therefore, the next approach is stated below.

B. Selected Edge-excited Zone Approach

In an edge excited zone approach, all the zone sites are moved from the center of the zones to the edges of the zones, and are also located on the perimeter of the cell boundary as shown in Fig. 2. The calculation of C/I in this edge-excited zone approach is based on the K = 3 configuration shown in Fig. 4. The center cell is the serving cell. One selected zone is serving the mobile call. The center of the cell is the weak spot for receiving the signal from the zone site. There are six interfering cells around the serving cell. Amongst the six interfering cells, three of which may have two zone sites in each cell to interfer with the mobile call in the center cell. The other three cells may have only one zone site in each cell to interfer with the mobile call. Since only one zone site is turned on at a time in a cell on any one frequency, the probability of interfering with the mobile call from each interfering zone site is one third. The distance from each interfering zone site to the vehicle can be obtained from Fig. 4. Three interfering cells, each of which has two C-zones which may interfer with the mobile call. However, the probability is only two-thirds. The probability that the remaining three interfering cells, each having one D-zone which may interfer with the mobile call is one-third. The C/I ratio is obtained at the vehicle from six co-channel cells (denoted"1") as

$$C/I = \frac{R^{-4}}{\underbrace{3\left[\frac{2}{3}(3.6R)^{-4}\right]}_{C\text{-zones}} + \underbrace{3\left[\frac{1}{3}(4R)^{-4}\right]}_{D\text{-zones}}}$$

$$= 63\,(=)\,18\,dB$$

In this edge-excited zone approach, the C/I can still be maintained at 18 dB which is the level for acceptable voice quality. Of course, the K = 3 configuration shown in Fig. 4 proves the increase of radio capacity. As we know, the onmi-zone approach still provides the best voice quality. There is another approach stated in the following section.

C. Non-Selective Edge-excited Approach

There are situations when all the zones have to be turned on. We call this a non-selective edge-excited zone configuration. In a non-selective edge-excited zone configuration, all the cells are treated as omnicells because all zones sites are transmitting concurrently. In an analog system, the regular center-excited omni-cells require the co-channel interference reduction factor qwhich is equivalent to q = D/R = 4.6 as mentioned previously.

In edge-excited zone cells, the D_1/R_1 has to be 4.6 in order to maintain the voice quality. Where D_1 is the channel zone separation and R_1 is the distance from the zone transmitter to the zone boundary, R_1 is also equal to the cell radius. Then new q ($q = D/R_1$) becomes 3.6 as shown in Fig. 5. Then the frequency reuse factor K becomes

$$K = \frac{(q)^2}{3} = \frac{(3.6)^2}{3} = 4.32 \approx 4$$

which proves that the edge-excited approach can increase the radio capacity by 7/4 = 1.75 times.

IV. Summary

The radio capacity can be increased by 2.33 times if a selective zone approach is used. The radio capacity can be increased by 1.75 times if a non-selective zone appraoch is used. The efficiency of using this Microcell configuration reaches a maximum because K = 3 is the smallest number in a frequency reuse system. When applying the analog system with a non-selective zone configuration, the radio capacity can be increased by 1.75 times. When applying microcells to CDMA systems, the non-selective-zone configuration can be used to further reduce the interference. The attributes of Microcell have been stated in Referene 4.

References

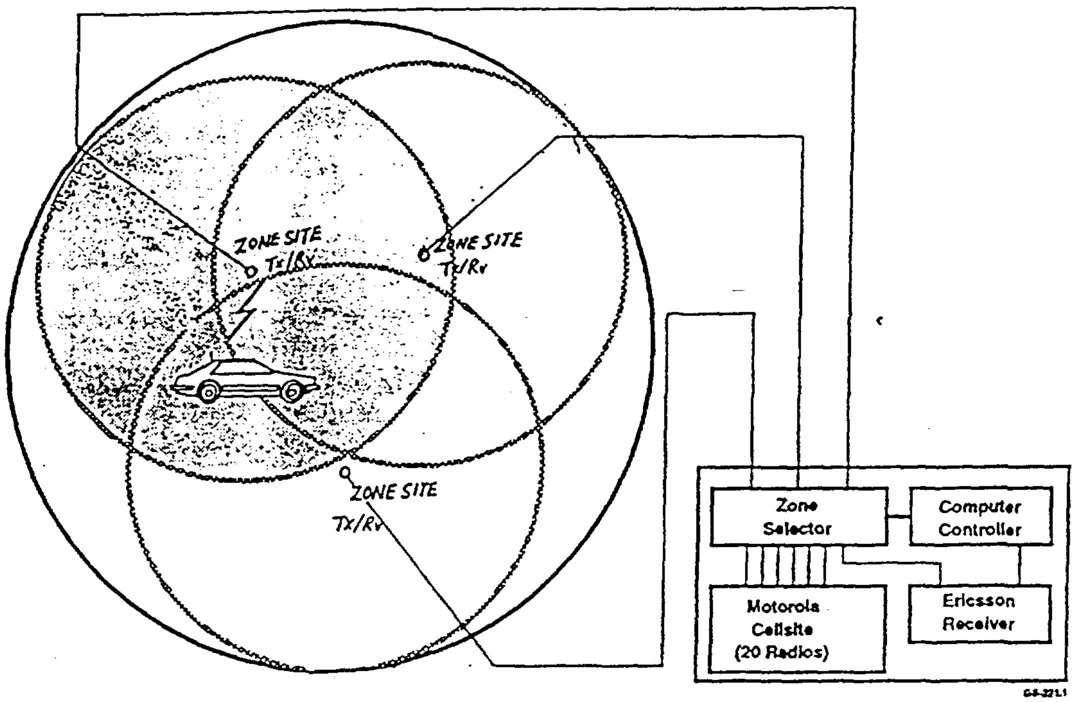
1. W. C. Y. Lee "Cellular Telephone System," U.S. Patent 4,937,049.

2. W. C. Y. Lee "Microcell Telephone System," U.S. Patent, Microcell System for Cellular Telephone Systems, 5067147, November 19, 1991.

3. W. C. Y. Lee "Mobile Cellular Telecommunications Systems," McGraw Hill, 1989, p. 57, p. 379.

4. W. C. Y. Lee "Microcell Architecture," IEEE Communications Magazine, November 1991, pp. 19-23.

Figure 1 Microcell Omni-zone Configuration



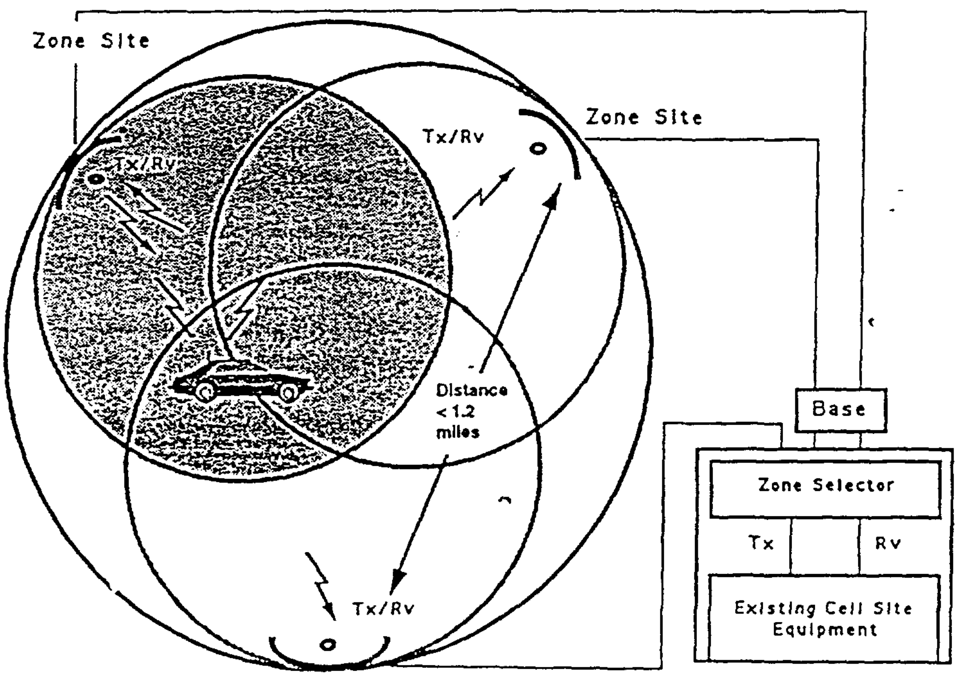
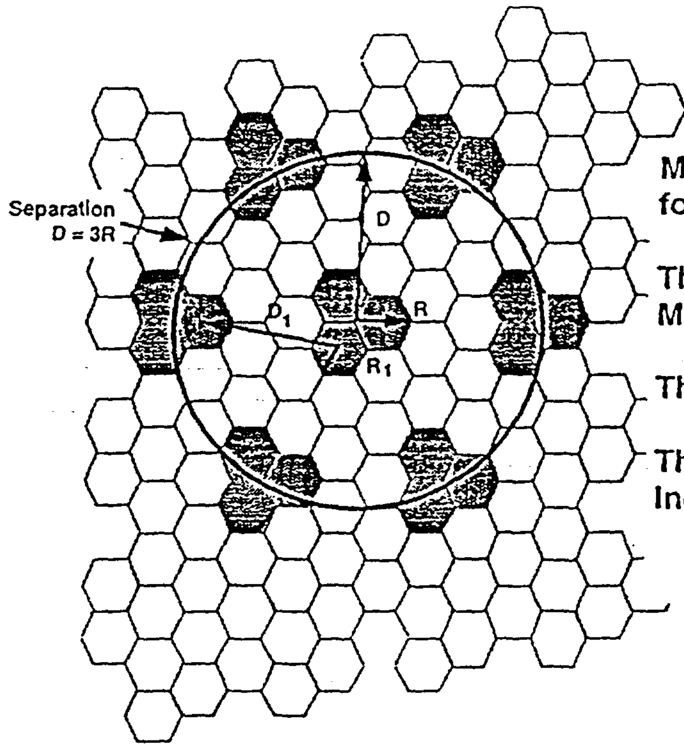


Figure 2 Microcell Edge-excited Zone Configuration



Microcell Utilizes $D_1 / R_1 \cong 4.6$ for Active Zone Separation

This Provides a D= 3R for Microcell Cell Separation

This Yields a K = 3

This is a 2-2.5 Capacity Increase

Figure 3 Microcell Application

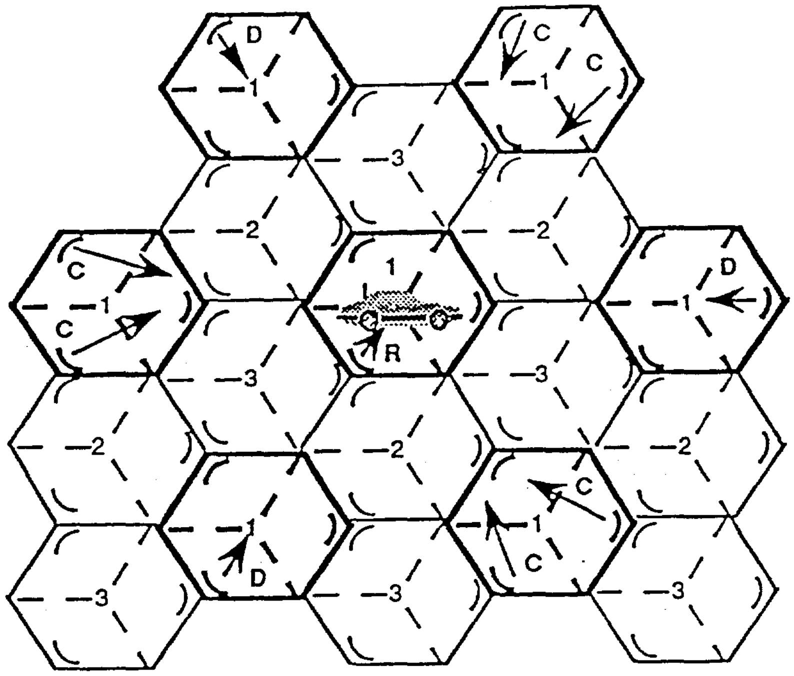


Fig 4   Configuration of the selective edge-excited zone cells

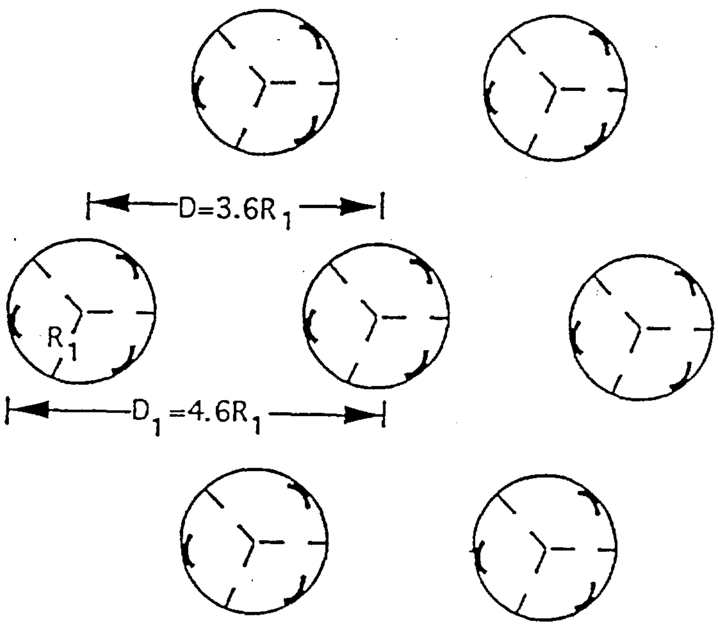
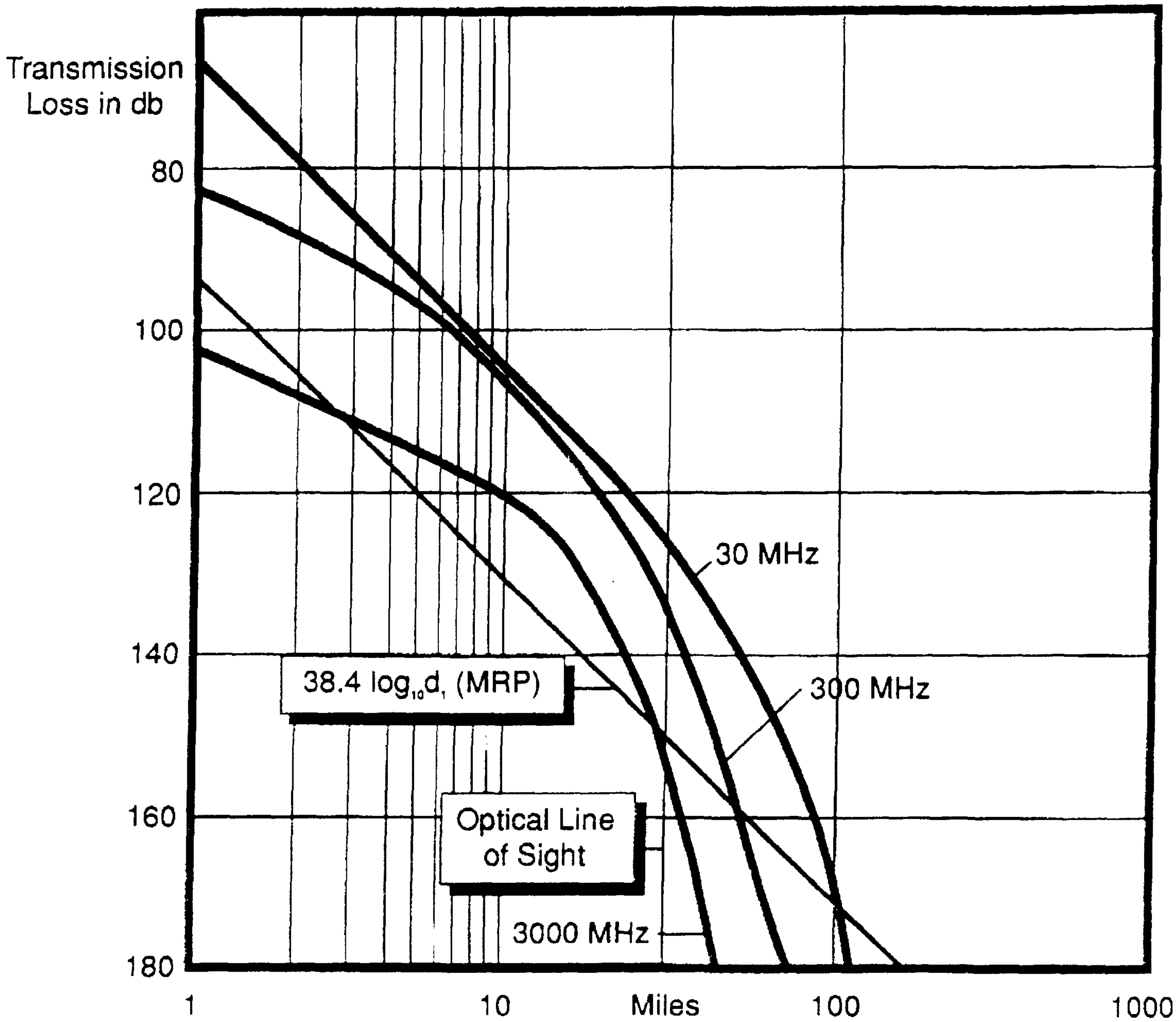


Fig 5 The configuration of the non-selective zone cells

Exhibit 5

Transmission Loss Over Smooth Earth

(at 30, 300 and 3,000 MHz; half-wave dipoles at 250 and 30 ft.)



Bullington, K., Radio Propagation for Vehicular Communications. IEEE Trans. on Veh. Tech. Vol. VT-26, No. 4, November 1977, p. 307.